Demonstration of FRP Composites for the Repair and Maintenance of Navigation Gates and Structures

ERDC
Engineer Research and Development Center

2014 Locks Maintenance Workshop
Smyrna, TN

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US Army Corps of Engineers®

Outline

- Background
  - Thermoset and Thermoplastic Composites
  - Nav Structures / Nav Systems
  - Collaborators
- R&D and Field Demonstrations
- Products / Other Opportunities

Background

- **Problem/Objectives**: Fiber reinforced polymer (FRP) composites offer the potential for repair of critical components of navigation systems at a reduced cost and greater durability than traditionally used. New Work Unit initiated in FY12 under Nav Structures focused on the used of FRP composites for rapid repair of navigation structures. Additional funding opportunities became available under Nav Systems to demonstrate and showcase the use of FRP composite materials in low risk but useful applications.
- **Collaborators**:
  - ERDC-CHL
  - Districts: Huntington, Louisville, Mobile, Nashville, Seattle, and Portland
  - NSF Center for the Integration of Composites into Infrastructure
    - West Virginia University and Rutgers University
  - Inland Navigation Design Center

- **R&D FRP Composites for Navigation Structures**

  - **FRP Composite Timbers for Guide Walls and Gates.** Lack of guidance and mixed success with use in the field.
  - **Replace Frozen Rollers on Lift Gates at Bankhead Lock & Dam, AL.** Replace rollers with polymer composite slides with no moving parts.

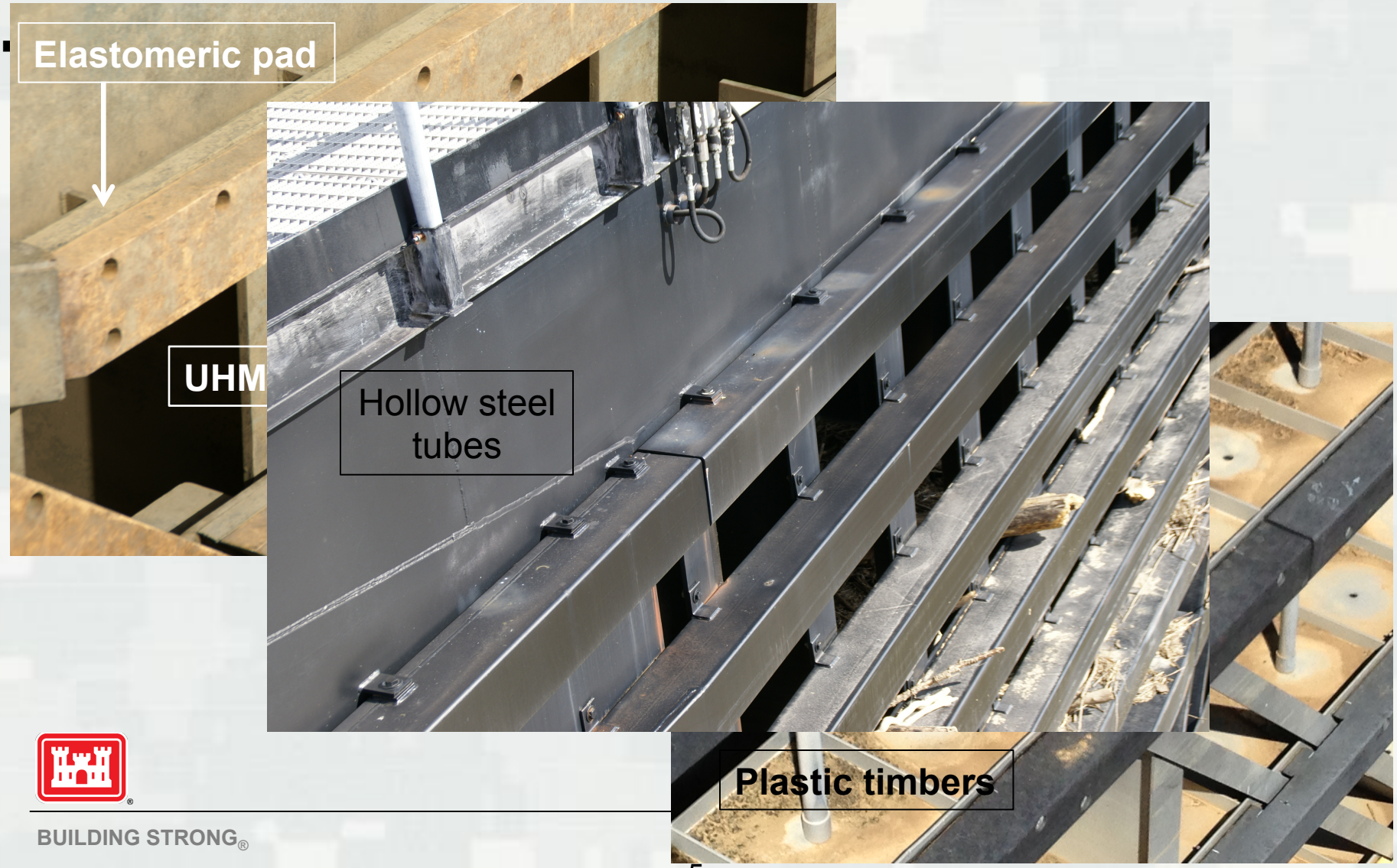
- ***The Following R&D Efforts Also Part of Demonstrations Being Executed Under Navigation Systems***

  (will discuss when talking about the other Nav Systems Demos)

  - **Rehab of Corroded Steel H-Piles, East Fork Bridge, Huntington, WV.** Bring load capacity back to original at 25% of cost using traditional methods.
  - **FRP Composite Wicket Gates.** Timber wicket gates: rapid deterioration, costly to replace. Stepping stone to future design and application of other larger FRP composite gates and valves.

Product Development Nav Structures

- **FRP Composite Timbers for Guide Walls and Gates.** Lack of guidance and mixed success with use.



Product Development Nav Structures

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Product Development Nav Structures

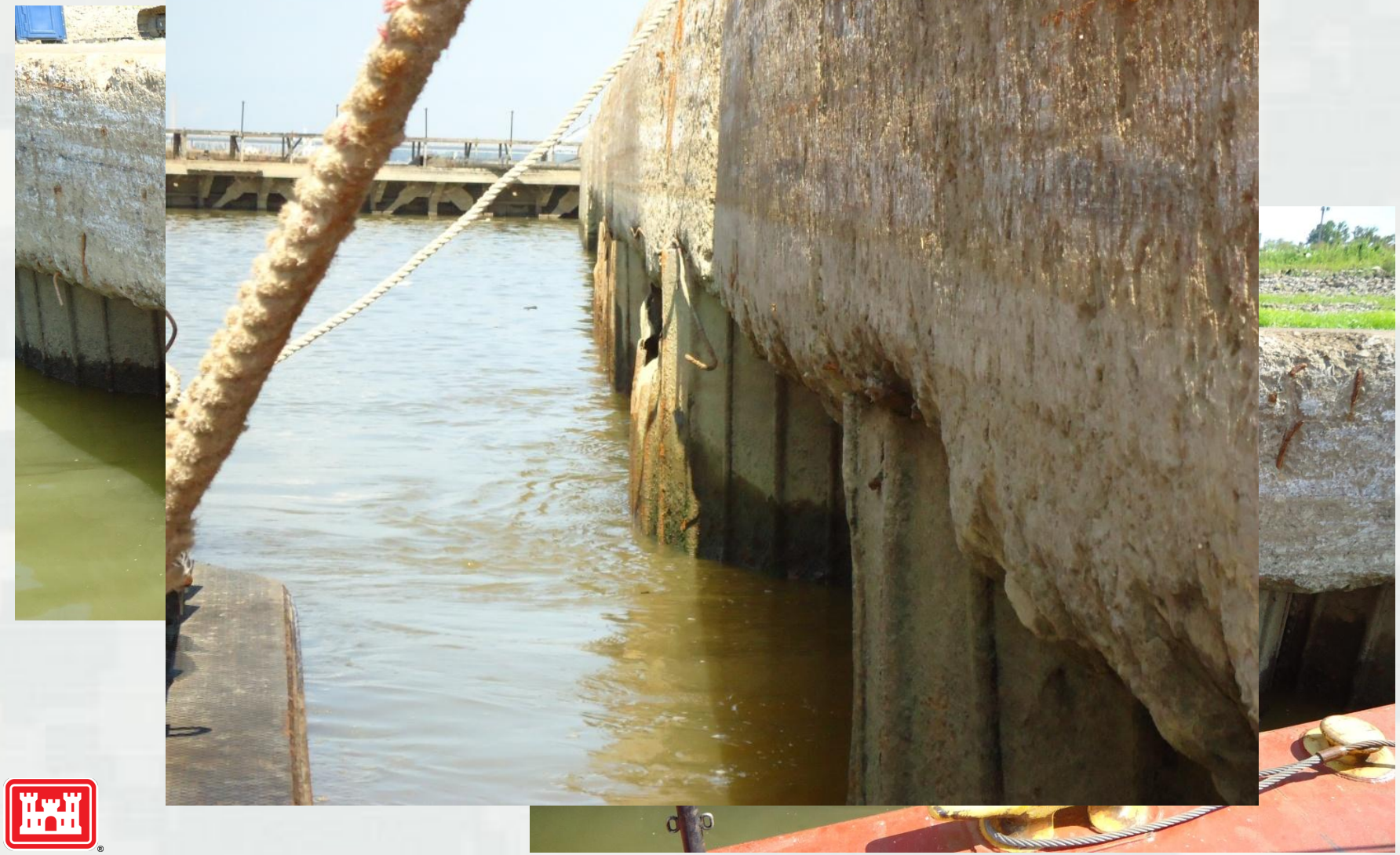
- **FRP Composite Timbers for Guide Walls and Gates.**

Product Development Nav Structures

- **UHMW-PE Rub Blocks – Bonneville Dam, OR**

Product Development Nav Structures

- **Wall Armor Needed L&D #52 – considering UHMW-PE sheets**



Product Development Nav Structures

- **FRP Composite Timbers for Guide Walls and Gates.**

Product Development Nav Structures

- **Replace Frozen Rollers on Lift Gates at Bankhead Lock & Dam in AL.** The reaction rollers cease up due to corrosion and drag when gate is raised or lowered. Design a repair using polymer composite glides with no moving parts.

Product Development Nav Structures

Replace Frozen Rollers on Lift Gates at Bankhead Lock & Dam in AL.

Replacing wheels on floating mooring bits with polymer slides.

Product Development Nav Structures

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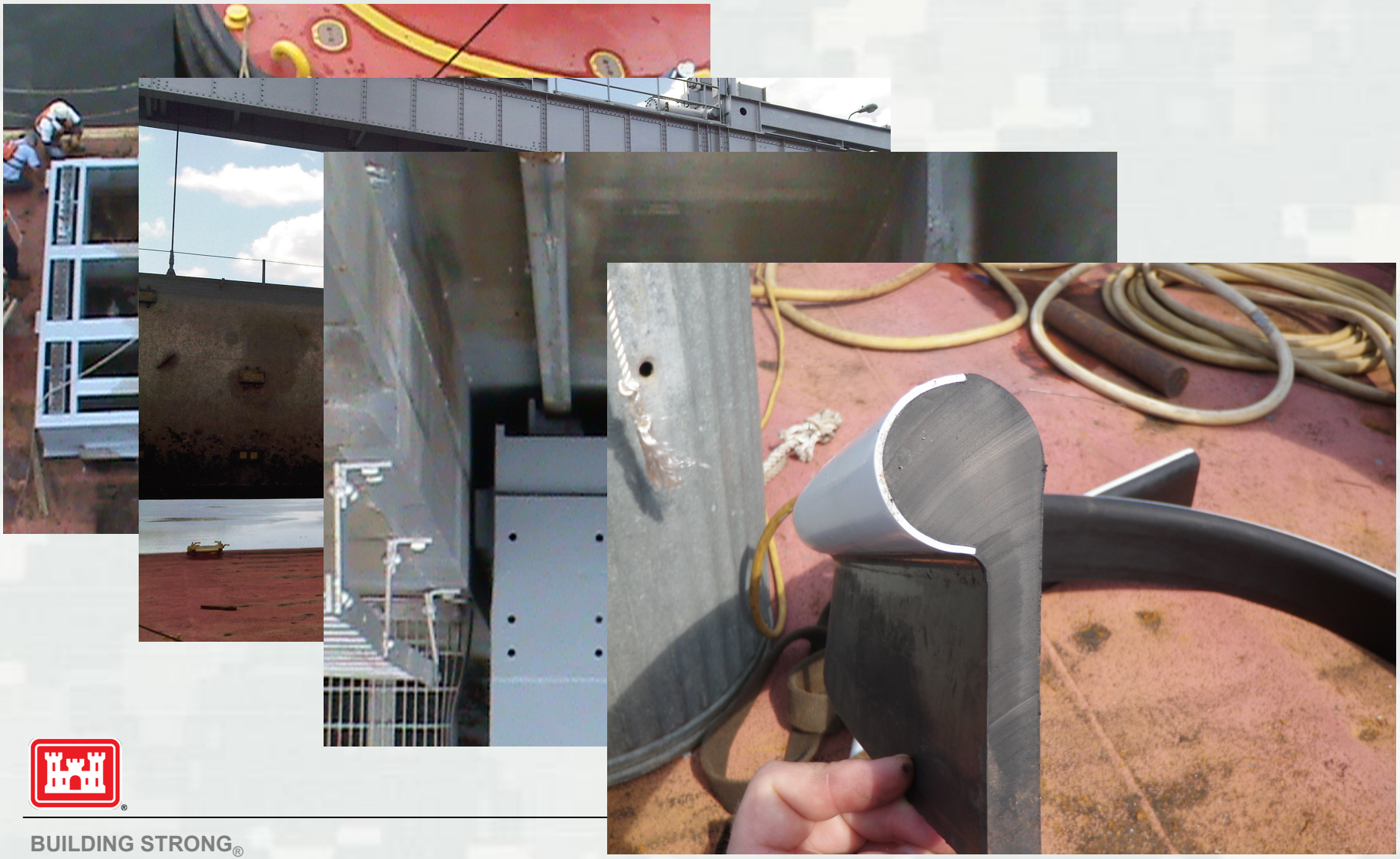


Product Development Nav Structures

Adhesively applied UHMW-PE for Slides

(Instead of mechanical fastening)

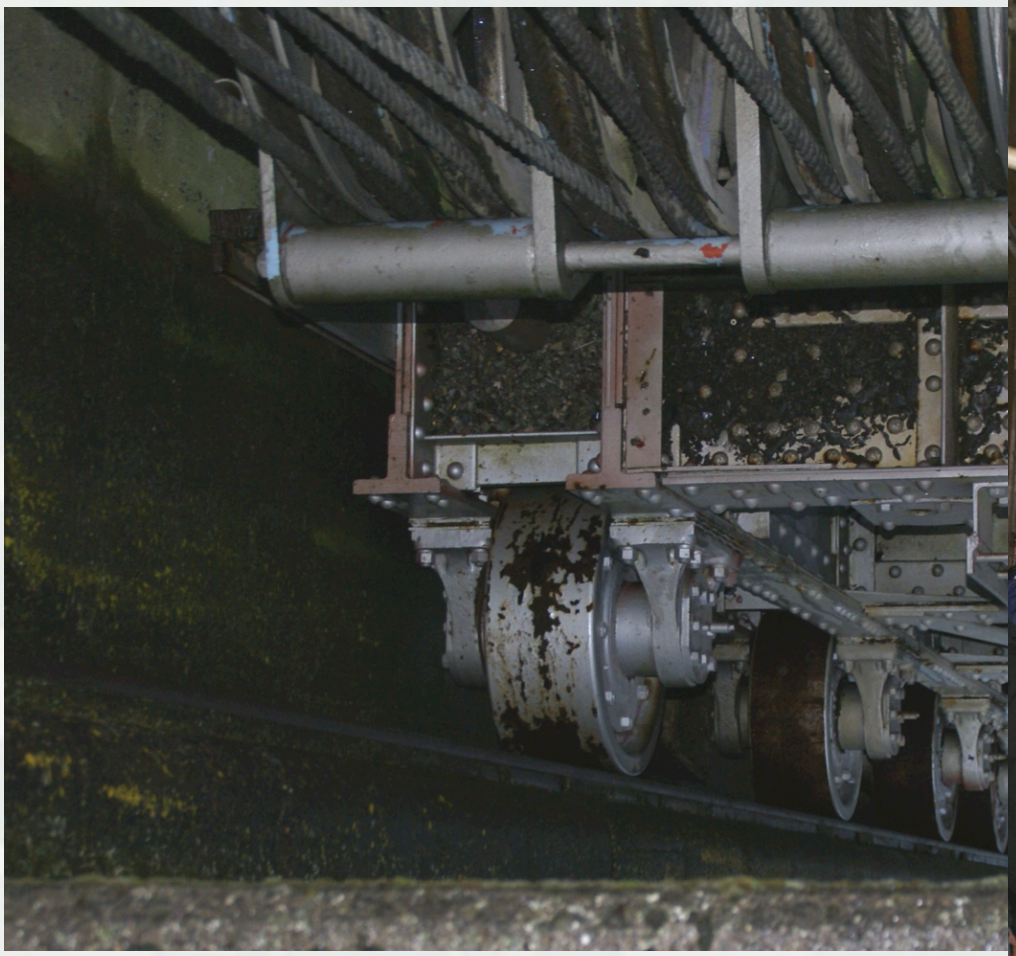
Product Development Nav Structures

Adhesively applied UHMW-PE for Slides

Product Development Nav Structures

Reimbursable – Replace Rollers on Lift Gates at Bonneville Dam

Taller gates, higher head than at Bankhe



FRP Composite Materials Demonstrations Under Navigation Systems

- **FRP Composite Miter Blocks at Washington Lake Canal, WA.**
  Non-corrosive and better sealing.
- **Repair Concrete Discharge Ports at Chickamauga Dam, TN.**
  Underwater curable composite wrap – easier and more durable than using steel jackets and grout.
- **Recess Filler Panels at Willow Island Locks and Dam, OH.** Steel panels costly, heavy, and they corrode – designed using off-the-shelf products.
- **Abrasion - Resistant Overlays for Tainter Gates at Heflin Dam, AL.**
  Swirling debris quickly damages traditionally used vinyl coatings.
- **Rehab of Corroded Steel H-Piles, East Fork Bridge, Huntington, WV.**
  Bring load capacity back to original at 25% of cost using traditional methods.
- **FRP Composite Wicket Gates.** Timber wicket gates: rapid deterioration, costly to replace. Stepping stone to future design and application of other larger FRP composite gates and valves.

FRP Composites Demonstrations

- **FRP Composite Miter Blocks for small lock on Washington Lake Canal, WA.** Blocks are 39 feet long on upper service gate and 19 feet long on lower service gate.

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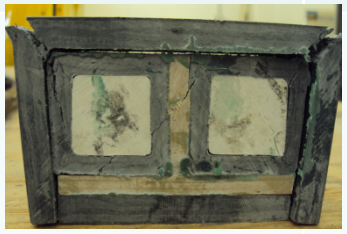
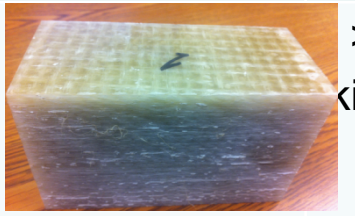
FRP Miter Blocks (4”x2.5”x2”)

Group	No. of Variations	Example	Load Range Kips	
I	5		Max. 84 kips (with core)	No-cracking & Group IV specimen is selected for field installation. Specimen provided ~ 51 ksi failure stress.
II	4		Max. 145 kips	
III	1		Max. 192 kips (at deflection limit of 0.23”)	
IV	1		> Max. is 224 kips (UTM limit)	

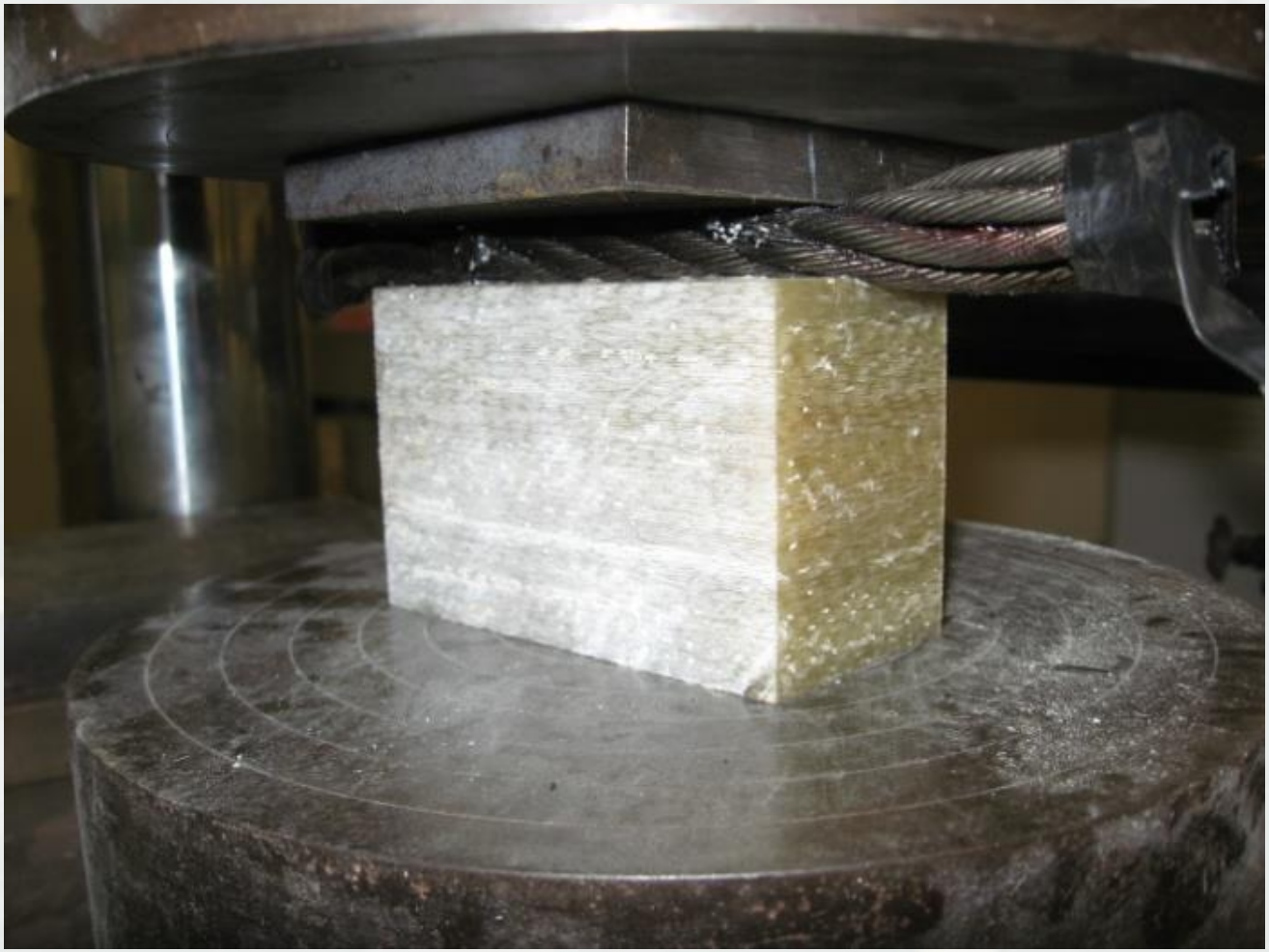
Note: Groups I & II consist of trimmed FRP tubes & plates with foam core or solid square tube cores. Groups III & IV consist of solid FRP sheets and block.

Selected FRP Miter Block-Stresses in 3-Directions

Group	Load Direction	Failure Stress	Failed Specimen	Comments
IV	Along the mitering surface	~ 51 ksi		Specimen: (4”x2.5”x.75”) Loading surface: (4”x0.75”)
	Between the steel channel edge surfaces	~ 22 ksi		Specimen: (4”x2”x1.5”) Loading surface: (2”x1.5”)
	Along the length (height direction in the gate)	~ 29 ksi		Specimen: (2”x2”x1.5”) Loading surface: (2”x1.5”)

Note: 1.4 ksi is required on the mitering surface vs. ~ 51 ksi (available)

Behavior When Pinching Foreign Object



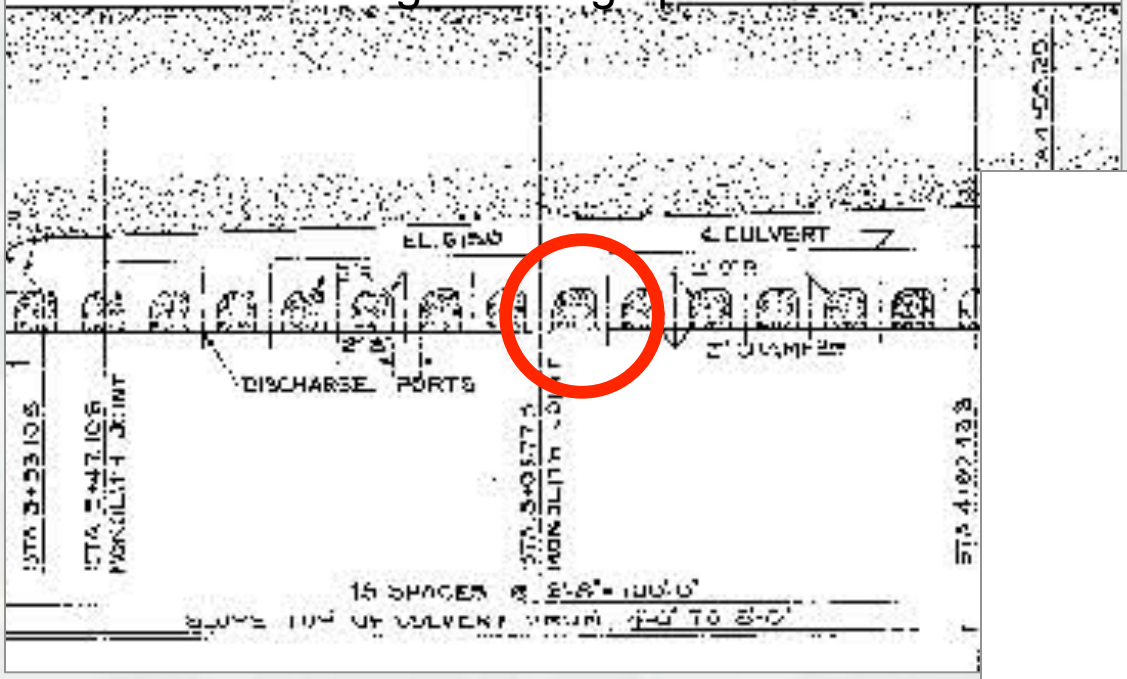
Results of Miter Block Pinch Tests

No	Specimen picture & dimension	Foreign Objects (Wire) Type	Diameter of the foreign object	Failure	Indentation on miter surface after testing	Load Deflection response
1	 (2"x4"0.8")	 Rebar	0.75"	None		0.12" at 50 kips
2	 Steel Plate(tested) (2"x4"x0.5")	 Rebar	0.75"	None		0.07" at 50 kips and 0.21" at 150 kips
3	 (2"x4"x0.8")	 Smooth steel bar	1.75"	None		0.13" at 50 kips
4	 (2"x4"x2.5")	 Steel cable	0.75"	None		0.21" (includes cable deflection) at 50 kips, 0.3" at 100 kips, 0.39" at 150 kips, i.e., ~0.09" for every 50 kips

FRP Composites Demonstrations

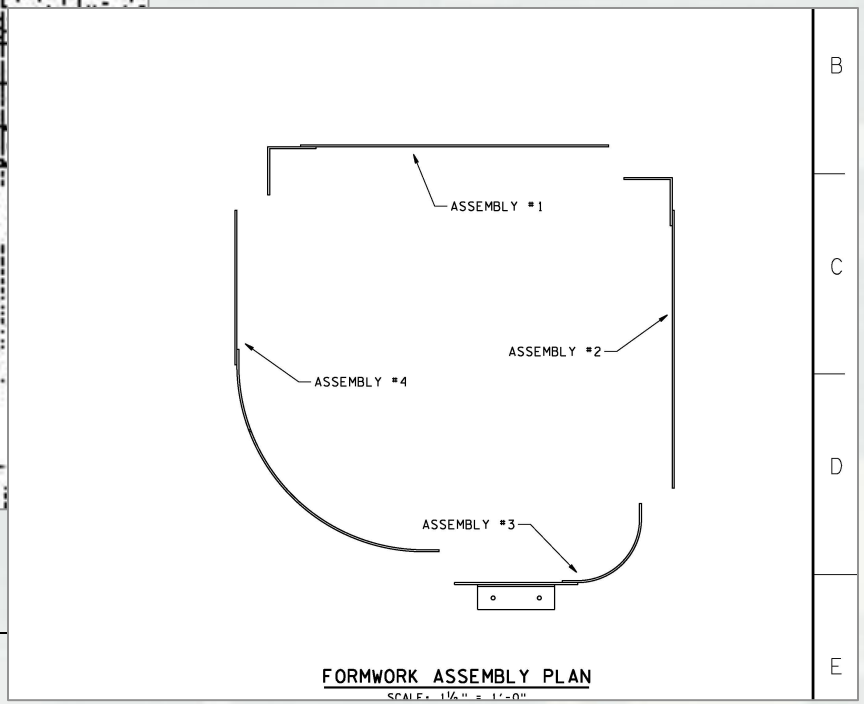
- **Repair concrete discharge ports at Chickamauga Dam in Tennessee.** Structural movement due to alkali aggregate reaction has caused cracks to develop on columns that define the discharge ports. Will repair using polymer mastic grout and composite wrap that cure underwater. Easier and more durable repair than using steel jackets and grout.

Schematic showing discharge ports in lock structure



Cracking concrete columns

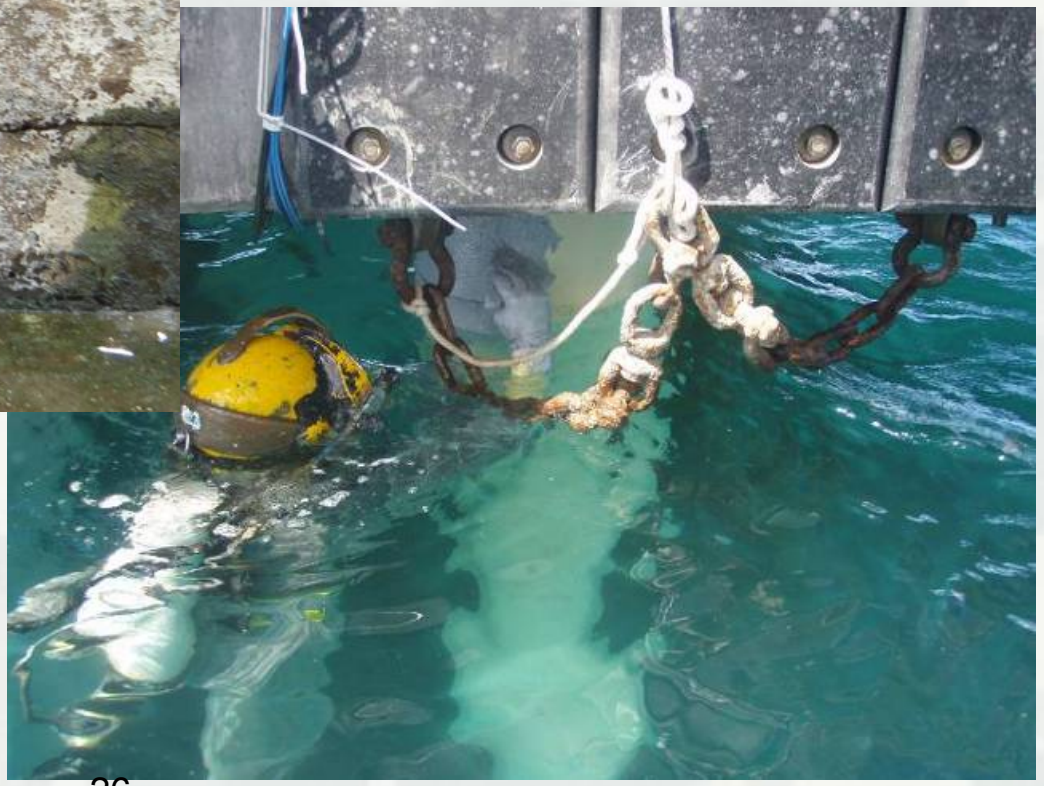
Steel repair shell
358 lbs total weight !



FRP Composites Demonstrations

Repair concrete discharge ports at Chickamauga Dam in Tennessee.

Example cracking at exit ports.



Driver applying composite wraps on concrete piles underwater.

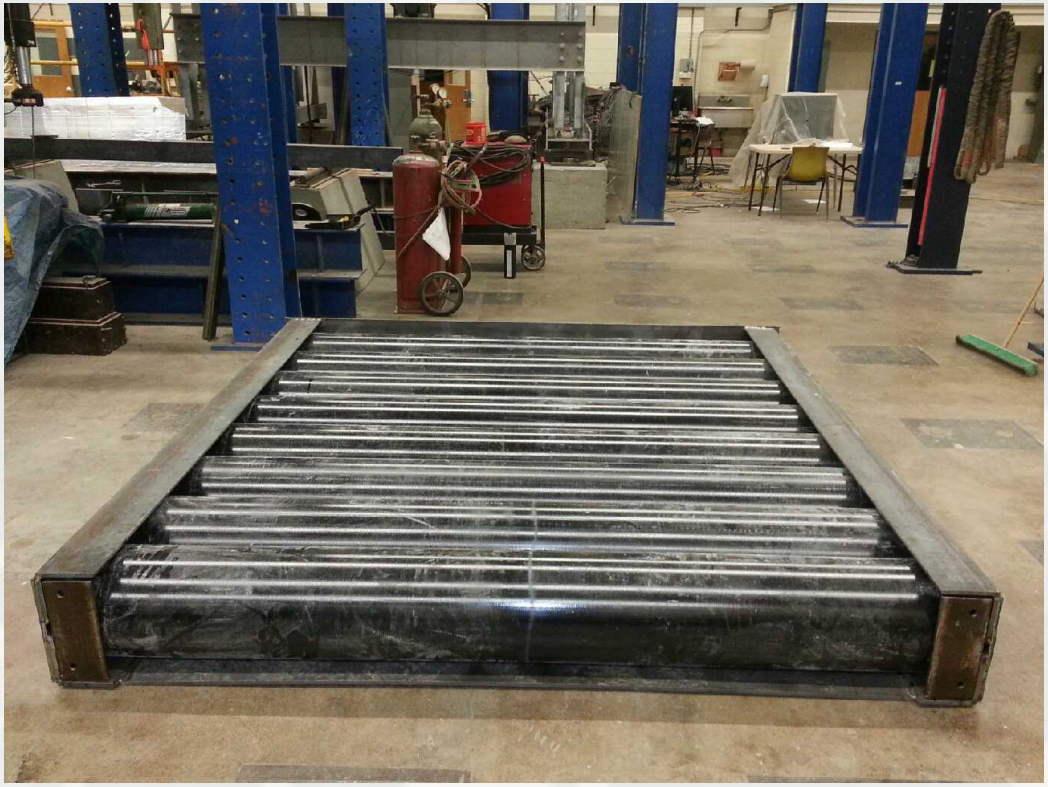
FRP Composites Demonstrations

Repair concrete discharge ports at Chickamauga Dam in Tennessee.

FRP Composites Demonstrations

- **Recess Filler Panels at Willow Island Locks and Dam, Ohio.** Steel panels costly, heavy, and they corrode.

Current steel panels



Initial tube and plate design

FRP Composites Demonstrations

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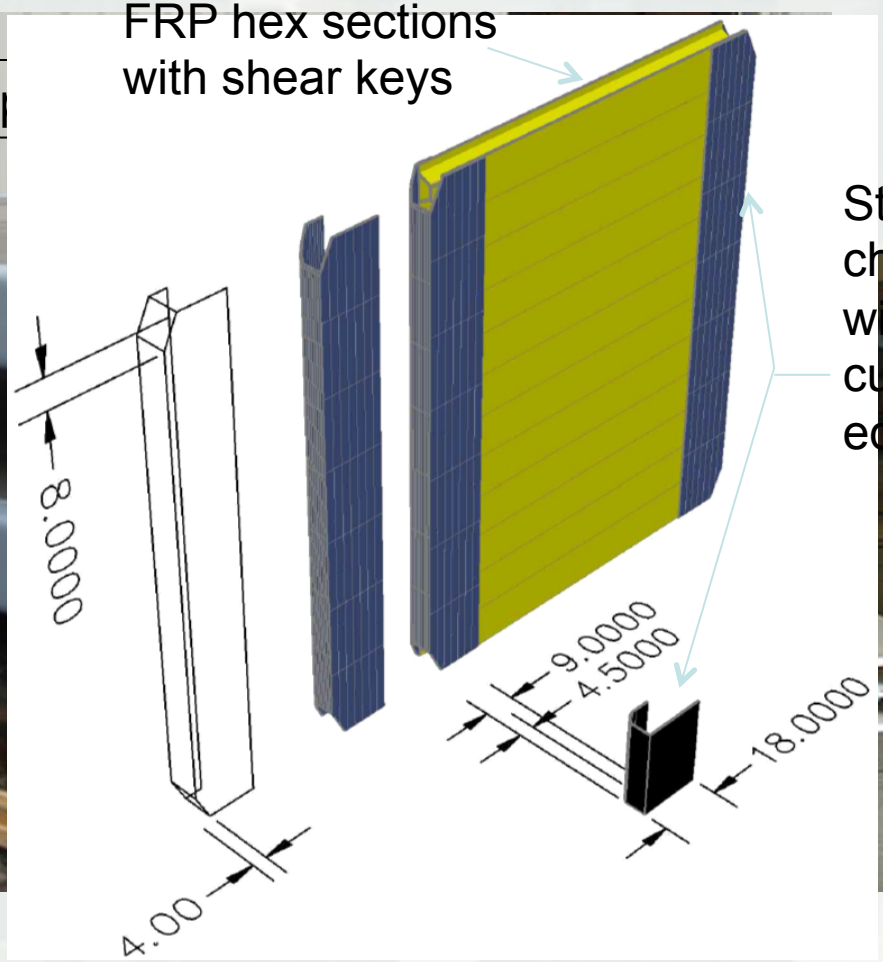
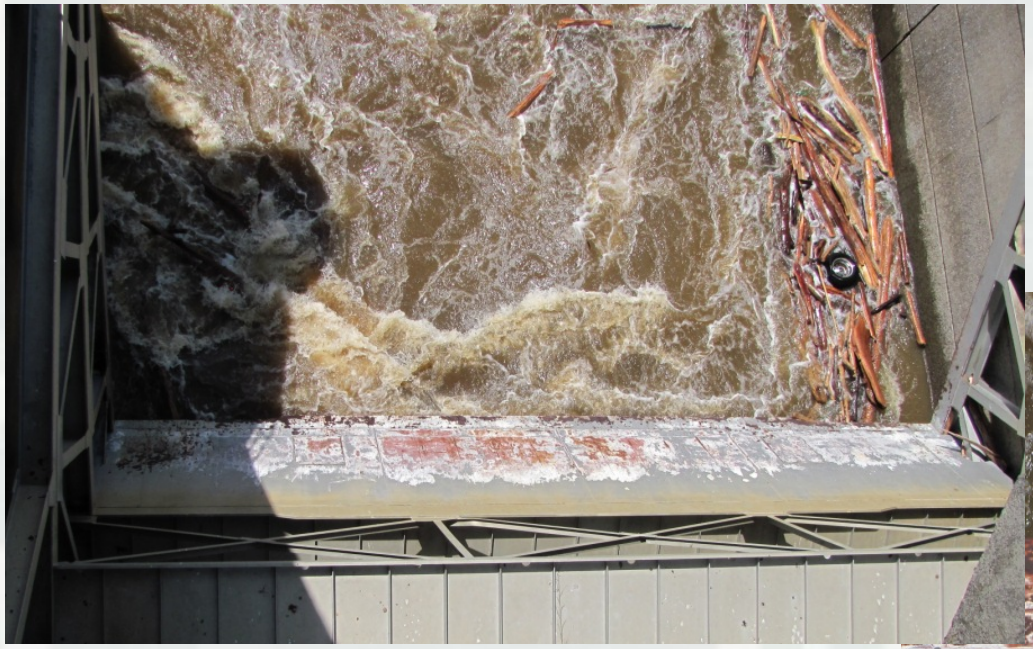
Lab testing



Final design

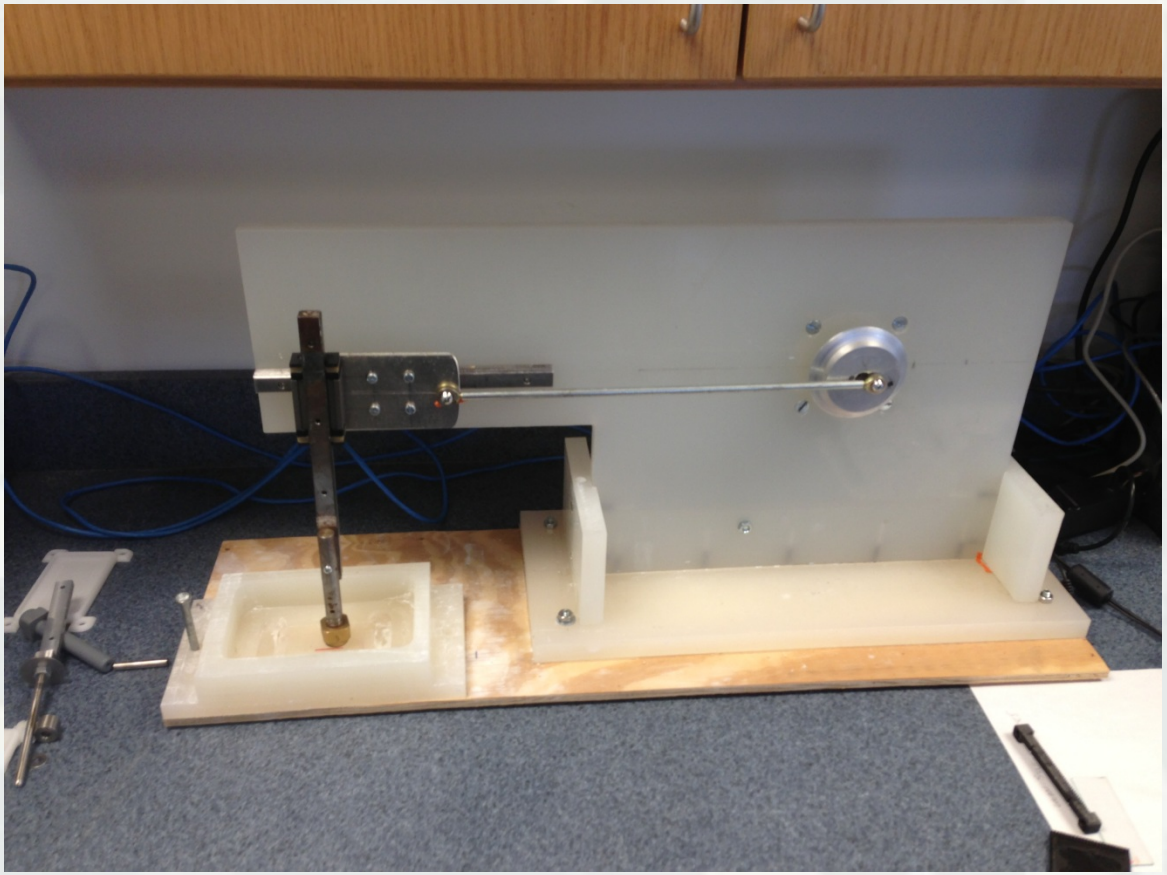
FRP Composites Demonstrations

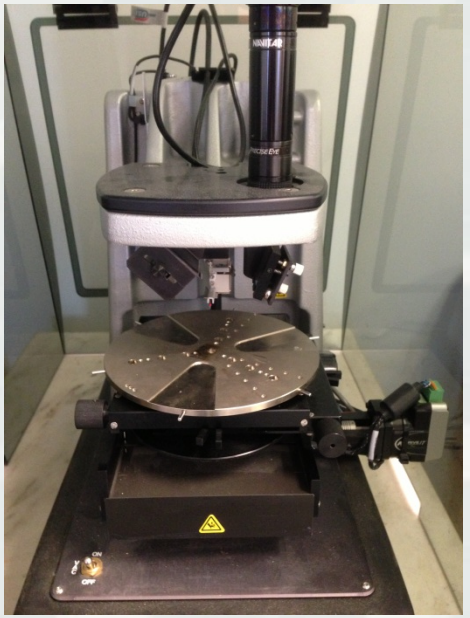
- **Abrasion - Resistant Overlays for Tainter Gates at Heflin Dam, AL.** Swirling debris quickly damages traditionally used vinyl coatings.



Use organic and ceramic composites for overlays

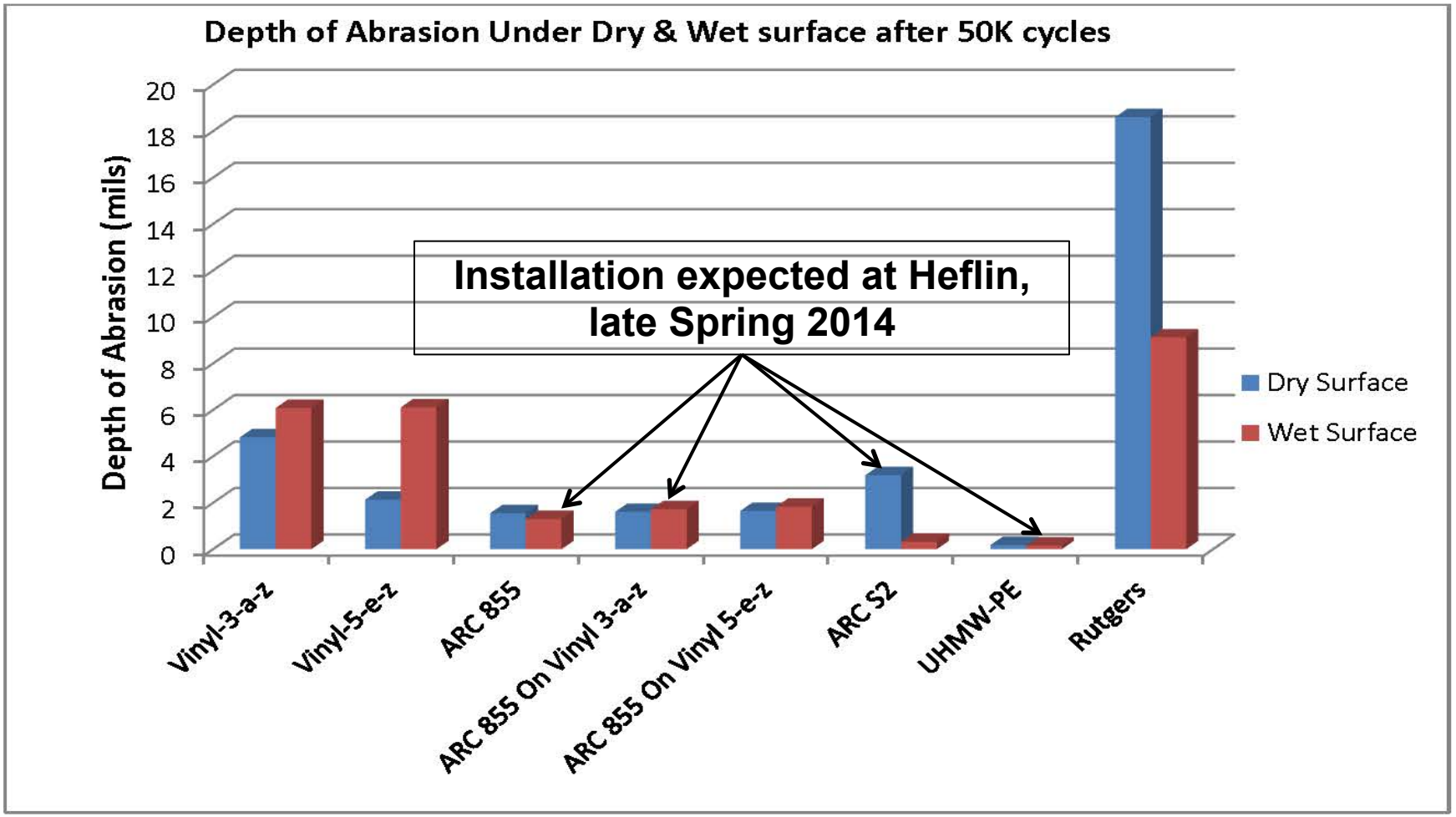
Laboratory Abrasion Testing





Reciprocating Abrading Steel Ball System (L) with Computerized Control & Profilometer (R)
(Note: the tank will accommodate both securing of specimen and conditioning with liquid)

FRP Composites Demonstrations



FRP Composites Demonstrations

Rehab of Corroded Steel H-Piles, East Fork Bridge, Huntington, WV.

Bring load capacity back to original at 25% of cost using traditional methods. Use composite shell, wrapped, and then filled with grout. Funding for rehab from Huntington District and FHWA; Nav Sys supporting R&D activities associated with rehab.

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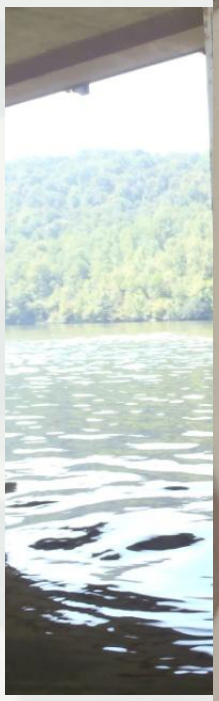

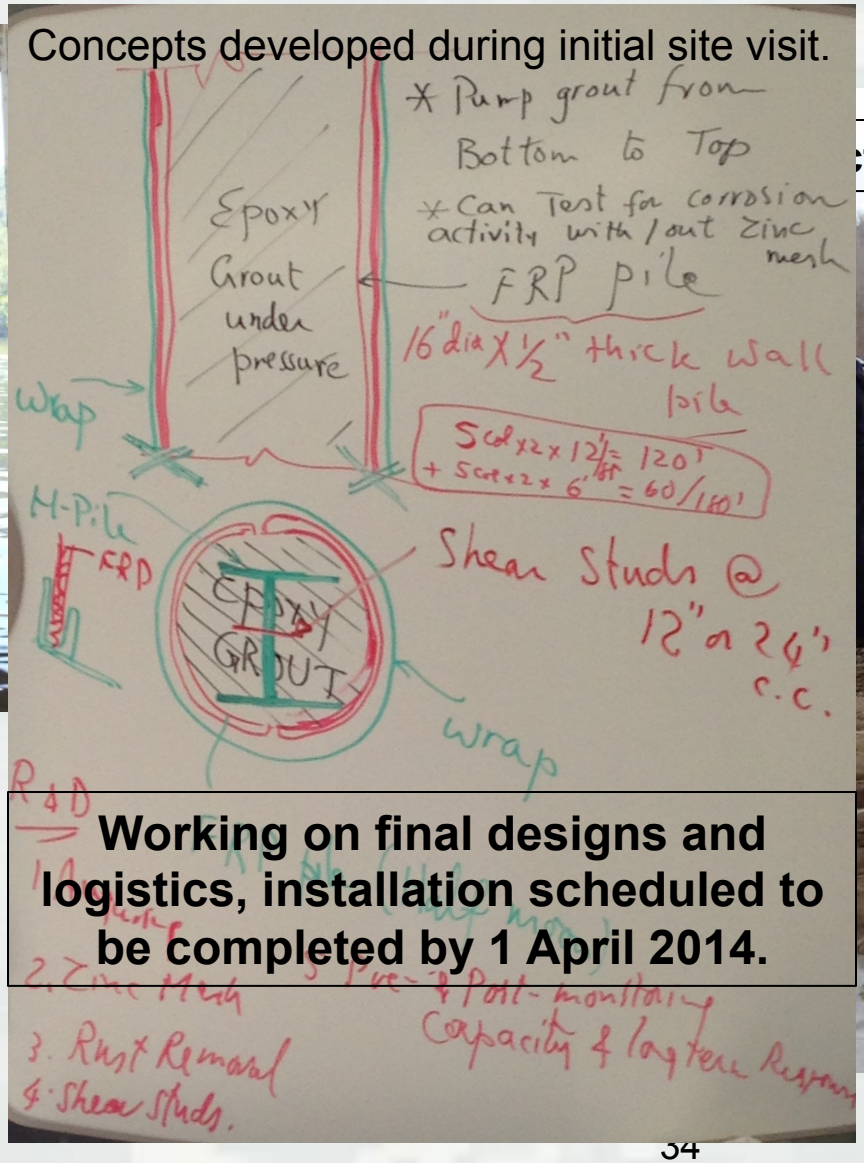

Working on final designs and logistics, installation scheduled to be completed by 1 April 2014.

FRP Composites Demonstrations

FRP Composite Wicket Gates. Timber wicket gates: rapid deterioration, costly to replace. Stepping stone to future design and application of other larger FRP composite gates and valves. Prototype gates will be developed using both thermoset and thermoplastic composites. To be installed at L&D #52.

Traditional wooden wickets

Near-Term Products / Opportunities

- Tech Note and Design Guidance for Polymer Slides on Gates (INDC).
- Tech Note and Design Guidance for Gate Bumpers and Polymeric Fenders (INDC).
- Technical report on the different demonstrations to include economic analysis of benefits.
- Assistance applying technology at your location.
- Suggestions from the field for use of FRP composites for other applications / components on navigation structures.

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Discussions/Questions ???

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